Knowledge-driven Problem Solving Models in Nurse Education

Krystyna Cholowski
Department of Community and Mental Health Nursing
University of Newcastle
NSW, 2308.

and

Lorna Chan
Department of Education
University of Newcastle

Paper to be presented at the Joint AARE/NZARE Conference,
Deakin University, 22-26th November, 1992.

Abstract

This paper compares the hypothetico-deductive model of clinical problem-solving commonly used in current nurse education and practice with the knowledge-driven problem-solving model (Bordage, Grant & Marsden, 1990). It will be argued that the knowledge-driven model provides a more complete account of the processes involved in clinical problem solving. These propositions emphasise the organisation and availability of relevant content knowledge stored in memory as the prime determinant of clinical problem solving. This contention is discussed in relation to the development of clinical problem-solving tasks for nursing students.

Knowledge-driven Problem Solving Models in Nurse Education

The capability of nurses to define and manage clinical problems has been identified as a central component of clinical competence in nursing (Jones, 1988; Itano, 1989; Carnevali, 1984). In recent years the question of how best to teach nursing students to develop problem solving skills has become an issue of major importance to nurse educators and a prime educational objective in most nursing schools.

Many efforts to promote these skills in nursing have been founded on certain common assumptions about the nature of clinical problem solving. Among these is the assumption that the problem solving skill is dependent on a set of generalisable processes, largely independent of relevant content knowledge (Neufeld, Norman, Feightner & Barrows, 1981). Thus, differences in performance is considered to be the result of a lack of understanding of the principles of problem solving process. These assumptions have more recently come under question. In particular, recent research has challenged the idea that problem solving processes alone are sufficient to explain the development of expertise and has begun to emphasise the role of content knowledge in explaining clinical problem solving.

In this paper two approaches to clinical problem solving in nursing will be considered. The paper compares the hypothetico-deductive model of clinical problem-solvingcommonly used in current nurse education and practice with knowledge-driven problem solving models (Bordage, Grant & Marsden, 1990). It will be suggested that these two models represent fundamentally different approaches to the study of clinical problem solving. Where the hypothetico-deductive model represents a process of deductive reasoning that sustains definable procedures, knowledge driven models focus on the organisation and availability of relevant content knowledge stored in memory as the key component of clinical problem solving. It will be argued that knowledge-driven models provide a more complete account of the processes involved in clinical problem solving. This contention is discussed in relation to the development of a clinical problem solving task for nursing students.

Hypothetico-deductive Model

The hypothetico-deductive model has been described as a general heuristic that draws on Bruners's account of discovery learning in education and promotes the notion of self-directed learning (Laurillard, 1989). The problem solving process begins by selecting a few cues from the clinical problem at hand in order to formulate several broad initial hypotheses (Barrows & Tamblyn, 1980; Ellis & Hunt, 1989; Kagan, 1988). This forms a basis for a hypothesis-orientated inquiry where the hypotheses serve as guides to identify the need for further information (Carnevali, 1984). Newly gathered information helps to refine and reformulate problem definitions against which each working hypothesis is tested.

Subsequently, more specific hypotheses are generated which in turn narrow the search for further information. At this point, unsatisfactory hypotheses are set aside and new ones generated (Barrows & Feltovich, 1987; Jones, 1988). Thus, the deductive process acts as a generator of hypotheses which are then tested and the hypotheses themselves are reduced until finally the nurse may decide upon the best solution.

The purpose of instruction under the hypothetico-deductive model is to promote the acquisition of the problem solving processes by moving the student through several cycles of data identification, hypothesis generation, information gathering, problem reformulation and hypothesis evaluation. Under these assumptions the goal of self-directed learning is to enable the students to develop the skills necessary to identify where their knowledge is inadequate, then obtain and use the content knowledge needed to complete the task (Clarke, 1988). The acquisition of the hypothetico-deductive processes is the necessary condition for expert problem solving as these processes are seen as generalisable across all problems. According to Norman (1988) the model has several distinct advantages when applied to educational settings. Firstly, the process can be made explicit to students, it can be easily understood and it provides good technique for teaching students to think systematically about clinical problems. Finally, it gives students an easily comprehensible explanation of problem solving behaviour.

The hypothetico-deductive model has been widely adopted in the nursing literature and is the most frequently used model in the study of problem solving in nursing (Carnevali, 1984; Gordon 1980; Yeaw, 1979; Holbert & Abraham, 1988; Jones, 1988). The processes espoused by the model have become strongly linked with problem-based learning and have been extensively advanced and developed in nurse education (Little & Ryan, 1988; Yeaw, 1979).

One of the major limitations of the model, however, appears to be the inability of experts to describe their problem solving processes in terms of the hypothetico-deductive model (Bordage & Lemieux, 1991; Carr, 1991; Gale, 1982; McGuire, 1985). Subsequently researchers questioned the universality of the model and began to focus more specifically on the thinking processes involved in problem solving (De Volder & De Grave, 1989; Gale & Marsden, 1983; Bordage & Zac, 1984; Groen & Patel, 1985; Bordage, Grant & Marsden, 1990). Researchers working from this perspective argue that content knowledge available to the individual for problem solving is the most important factor in predicting competence. What helps to improve student's problem solving is finding better ways of presenting the content knowledge to be acquired and finding ways of helping students structure their knowledge (Claessen & Boshuizen, 1985).

Knowledge-driven Models

Knowledge-driven problem solving models are based on the assumption that individuals typically try to understand new information on the basis of existing content knowledge (Glaser, 1984; Groen & Patel, 1985). This proposition emphasises the structure and accessibility of relevant content knowledge as a prime feature of clinical problem solving. Efficiently stored content knowledge is structured into networks (or schema) of information interconnected by rational links (Thompson, Ryan & Kitzman, 1990). It is this richly interconnected structure of knowledge that constitutes understanding and allows the individual to recognise and match clinical data with the appropriate schema. The expert is able to access this network readily, rapidly decide which clinical information is important, which cues are significant and how to integrate these data to make appropriate clinical decisions (Benner, 1984; Putnam, 1987).

Many different techniques have been used to examine various aspects of knowledge structure and its relationship to clinical problem solving. Subsequently a large array of knowledge-driven models have been introduced into the literature. A model of "semantic networks" describes problem solving in terms of abstract diagnostic concept that subsume clinical data and act to generate meaningful relationships between data items (Bordage & Lemieux, 1991). Schmidt, Norman & Boshuizen (1990) refer to "illness scripts", to describe the extensive schematic networks that develop with expertise. Bordage & Zac (1984) refer to a problem solving method where "prototype categorisation" is based on overlapping attributes of information rather than distinctive features. In a similar vein Norman, Lee, Brooks, Allen & Rosenthal (1990) describe problem solving in terms of "instant based categorisation" where the currently processed information is tied to a rich network of similar examples.

Although each of these models retains its own focus on knowledge and problem solving, their common underlying theme suggests that clinical problem solving competence results from a highly personalised body of knowledge which is structured in such a way that it can be easily retrieved from memory to be applied to the case at hand (Carr, 1991).

Research Findings Related to the Hypothetico-deductive Model

Perhaps the most comprehensive report on the Hypothetico-deductive model is the work of Elstein, Shulman and Sprafka (1978). The study extensively examined the cognitive activities of expert and novice physicians while formulating solutions to a difficult and uncommon clinical problems. Elstein found that both expert and novices used a single generalisable problem solving process similar to hypothetico-deductive reasoning. However, the research has been questioned for its use of retrospective verbal protocols. According to Patel & Groen such retrospective methods are likely to elicit data regarding the subject's own conception

of problem solving rather than how the subject actually went about the task.

Nonetheless confirmatory evidence for the idea of a generic deductive problem solving process has been reported by Barrows and colleagues (Barrows & Bennett, 1972; Neufeld et al, 1981) using in situ analytic techniques. Barrows & Bennett's (1972), for example, used simulated patients and found less experienced neurologists were more routine in their information gathering and generated slightly fewer hypotheses when compared to expert neurologists. Neufeld, Norman, Feightner & Barrows (1981) used video stimulated recall with a cross-sectional and longitudinal sample of subjects. The researchers found that all clinical encounters begin with early hypothesis generation leading to data collection and a hypothesis generation consistent with the hypothetico-deductive process.

One of the major problems with this research is not so much with the problem solving processes described but that these processes do not seem to generalise with equal success across different clinical problems (Berner, 1984). There is a wide literature reporting correlations of 0.3 or less across measures of the clinical problem solving process, suggesting that logically identical problems are solved in different ways producing different solution (Bornor & Durrell, 1987; ; Norman, 1988; Norman, Tugwell, Feightner, Muzzin & Jacoby, 1985; Neufeld, Norman, McAuley, Repo & Henry, 1983; Pavin,Neufeld, Norman, Walker Whelan, 1986). Data investigating the internal consistency and validity of measures of problem solving process seem to indicate low transfer of the problem solving process regardless of the nature of the problem or the scoring method used (Schmidt, Norman, Boshuizen, 1990).

A second major difficulty with the research on problem solving process is that the model has not been able to account for the differences between expert and novice problem solving. Studies comparing expert and novice problem solving have consistently found that regardless of experience, all individual use that same problem solving processes. Clearly, however, expert problem solving is more efficient than that of the novice (Balla, Biggs, Gibson & Chang, 1990; Bordage et al, 1990; Grant & Marsden, 1988; Laurillard, 1989). The only differences found related to the quality and accuracy of the hypotheses generated and on the accuracy of the diagnosis (Kaufman & Patel, 1991; Neufeld & Norman, 1985). However, this is not feature of the hypothetico-deductive process itself. Moreover, differences in the quality and accuracy of hypotheses are likely to a product of the content knowledge used in problem solving. It seems then that all individuals may use the same strategies or processes in problem solving but that differences in problem solving skill may relate to the content knowledge used in problem solving (Claessen & Boshuizen, 1985). Subsequently, more recent research moved away from the study of a general problem solving process to

focus on the structure and accessibility of the content of knowledge used to solve clinical problems.

Research Findings Related to Knowledge-driven Models
Using simulated patients and stimulated recall, Gale (1982) and Gale & Marsden (1982) have shown that clinical interpretation depends upon the recognition of personally

relevant data items that activate relevant knowledge structures. In two later studies, using written case histories, Grant & Marsden (1987, 1988) provided evidence for the first time of consistent differences in the knowledge structures of expert and novice physicians. The earlier study required subjects to link their diagnostic impressions with the data item that gave rise to the idea, while in the later study short introductory sentences were used to prime the knowledge actually used to solve the specific clinical problem. The researchers suggest:

"that the qualitative changes in knowledge that seem to occur with increasing experience begins with narrow, idiosyncratic and inappropriate memory store, through increasing breadth and similarity to the final characteristic of a perhaps slightly narrower, useful and finely tuned primary knowledge base which has been organised to respond to the demands of clinical problems and practice" (Grant & Marsden, 1988; p.178).

Grant & Marsden's results imply that the development of expertise in problem solving is not merely adding to a pool of knowledge but rather, such expertise develops as content knowledge is used in response to contextual demands. This suggests that as knowledge is used in problem solving, exemplars are built up using principles that allow the restructuring to occur. Thus the more knowledge is used the more sophisticated and efficient the structures become (Glaser, 1984). This notion that knowledge becomes associated with and changed by contextual demands is consistent with Bordages's research on semantic structures (Bordage, 1991; Bordage, Grant & Marsden, 1990; Bordage & Lemieux, 1991; Bordage & Zack, 1984).

Bordage's research is primarily concerned with how experts use their knowledge to generate highly structured representations of diagnostic information. This allows for re-conceptualisation of diagnostic information (eg. "three times in the last two days" becomes "acute and intermittent"). In turn these structures help to yield diagnostic decisions. In one study Bordage & Lemieux (1991) used written case studies from neurology and gastroenterology and asked their subjects (24 students and 5 neurologists) to think aloud while proposing possible solutions. The findings suggest that the most successful problem solvers are those who used the clinical data to build coherent network of relationships and therefore constructed a "deeper" memory representation of the problem.

Ramsden, Whelan & Cooper (1989) in comparing student approaches to solving a written diagnostic problem found that students who generated multiple links between clinical features and related this to etiological factors (content knowledge) were more likely to generate a better diagnosis that those who did not relate groupings of clinical information. Using nursing students, Cholowski & Chan (in press) found that the best predictor for the quality and accuracy of nursing diagnoses was the structure and complexity of student thinking as measured by the SOLO taxonomy (Biggs & Collis, 1982).

Knowledge based differences have also been documented on tasks related to clinical interview (Kaufman & Patel, 1991), recall and comprehension of clinical text (Groen, & Patel, 1988; Patel, Groen & Scott, 1988; Patel, Evans & Kaufman, 1990) and perceptual diagnostic tasks (Norman, Brooks, Allen & Rosenthall, 1990; Lesgold, Rubinson, Feltovich, Glaser, Klopfer & Wang, 1988). An important feature of these studies is the emphasis they give to the primary role of content knowledge in explaining clinical problem solving. The evidence from a wide array of clinical contexts indicates that success was dependent on a well structured knowledge base (Kaufman & Patel, 1991). Accordingly, this suggests that strategies to teach problem solving need to provide a mechanism through which nurses may develop well-organised knowledge structures that guide subsequent problem solving activities (Patel, Evans & Groen, 1989).

Teaching of Clinical Problem Solving

More often the teaching of clinical problem solving in nursing emphasises the general processes reflected in the hypothetico-deductive model. This is clearly seen in the widely espoused "nursing process" (includes four clearly defined steps of assessment of clinical data, diagnosis, implementation of interventions and evaluation of the interventions) and in most problem-based nursing curricula (Little & Ryan, 1988; McMillian & Dwyer, 1989; McMurray, 1989). Typically clinical problem solving is taught by asking students to systematically search for information by assessment, to generate large numbers of working hypotheses and to discuss the clinical problem emphasising the deductive procedure used.

However, procedural approaches to the teaching of clinical problem solving are not sufficient on their own to promote the development of more accessible knowledge structures. Silver & Marshall (1990) maintain that an important component of successful problem solving is "an adequate store of domain-relevant knowledge" (p.266), particularly "extensive and accessible knowledge" (p.267). It is contended that effective instruction to enhance successful problem solving is to make explicit certain implicit aspects of the knowledge needed for problem solving. These include firstly, visual pattern recognition, involving the rapid observation of regularity in patterns of information typically observed in clinical problems; and secondly, the underlying organisation of the

knowledge into hierarchies or into clusters of related concepts and procedures.

Regarding pattern recognition, research indicates that certain features of a problem, once recognised, may trigger particular solution methods (Clement, 1983; Davis, 1984). Hence drawing students' attention to regularities and patterns associated with typical clinical problems during instruction could assist students in developing pattern recognition skills that would enhance their problem solving performance. As for knowledge organisation, it is suggested that all clinical problem solving involves the retrieval of information from one's store of relevant knowledge and that the efficient retrieval of information during problem solving may depend on the way that information is organised in long-term memory, that is, the relevant memory schema. Problem solving research comparing experts and novices indicates that experts had much more richly connected schemas based on the underlying principles for problem representation, whereas novices had simpler and less complex schemas that focus only on surface features of problems (Chi, Glaser & Rees, 1981).

To improve problem solving performance, then, instruction must focus on modifying the organisation/structure of relevant knowledge stored in students' long-term memories. It is important to provide more organised instruction that will facilitate the development of well-structured, and hence more readily accessible schemas. Eylon and Reif (1984, cited inSilver & Marshall, 1990) demonstrated that students who were provided with hierarchical instruction that stressed the way concepts were related in the particular problems being discussed performed better on recall and problem solving tasks than students receiving nonhierarchical instruction.

The solving of routine problems can best be explained in terms of schemas as discussed in the above. When encountering problems that are not readily recognisable as belonging to a particular class, the construction of appropriate problem representation is critical (Silver & Marshall, 1990). In order to solve a complex clinical problem, the clinician must construct an understanding of the problem that connects his or her store of knowledge with the task requirements of the problem. This is called problem representation.

Unsuccessful problem solvers attempt to solve problems without constructing adequate memory representation of the problem definition (Silver & Marshall, 1990). Typically non-experts do not make use of related content knowledge but rather focus on current clinical data. Consequently the data are treated in a sequential and non-integrative fashion. This sequential processing does not yield a full understanding of the problem nor an understanding of the relationship between clinical data and the individual's content knowledge base (Balla et al, 1990). The novice's schema may contain sufficient information about the problem situation but lacks the knowledge of related principle and their application (Roth, 1990). This suggests

the possession of knowledge on its own is relatively "inert" unless the individual is aware of the extent of their own content knowledge and secondly the awareness of the need to utilise that knowledge in interpreting clinical data (Prawat, 1989).

Expert memory representation of the problem definition on the other hand, is typically organised around fundamental principles and concepts that subsume isolated details. These principles are derived from a content knowledge base that is characterised by complex networks of interconnected knowledge. Part of that interaction of old and new knowledge is the individual's awareness of the appropriate procedure to generate the links between the knowledge. Accordingly, procedural knowledge has a role in activating, accessing and using prior knowledge and the means for understanding new knowledge. Prawat (1989) argues:

"Being able to create an adequate representation of the problem is only half the battle, however. One must be able to relate this representation to a previous one that resulted in correct problem solution (Greeno, 1977). It is this relating of one problem situation to another that mediates access to potentially relevant conceptual and procedural knowledge" (p.16).

A key factor in accessible knowledge, therefore is the interconnectedness of pre-existing schema which in turn allows the individual to quickly identify what is important in the clinical data and how to integrate this data to make appropriate clinical decisions. In other words the richer and more elaborated the existing knowledge structures, the greater the possibility of generating appropriate diagnostic hypotheses. Accordingly, it may be argued that the effectiveness of the hypothetico-deductive model depends significantly on the richness of the underlying knowledge base.

Norman, Patel & Schmidt (1990) take the view that the development of accessible knowledge structure requires teaching methods directed towards understanding the way existing knowledge is organised as well as its relationship to the clinical problem at hand. Consistent with these concerns is research on learner-generated elaborations (Hamilton, 1990; Schmidt, 1983; Patel, Groen, Norman, 1991; Woloshyn, Pressley & Schneider, 1992). Learner-generated elaborations engage the student in a task constructing relationships between new and known information in order to justify their problem solutions. The elaborations explain how and why information from various sources is brought together. Thus students engage in the process of actively constructing meaning, actively thinking and puzzling about the problem and making personal sense of it (Roth, 1990). Therefore, students are assisted to modify relevant content knowledge to fit with the problem at hand to produce a more coherent and well-structured unit of knowledge. The increased structure should make the knowledge more distinctive and accessible, subsequently enhancing meaningful conceptual understanding. Analysing learner generated elaboration allows the instructor to identify what kinds of content knowledge are being used and how it is being used.

A Knowledge-driven Problem Solving Task in Nursing

Based on the assumption that accessibility of relevant content knowledge is of central importance to clinical problem solving a teaching strategy for problem solving in nursing was formulated. In this context accessibility of content knowledge is the presumed to be function of two important factors including the organisation of the knowledge, and the procedures that are available to deal with that knowledge. Subsequently, that strategy attempts to shift the focus from a deductive process to a more interactive approach. The purpose of the strategy is to help students to become aware of their reasoning processes and how the content knowledge they acquire can become progressively more useful to them in real-world clinical situations (Grant & Marsden, 1987).

The task involves presenting a case history that calls upon students to generate a nursing assessment for the case described. This sub-task provides an indication of the student's ability to collect, interpret and organise clinical information as a prelude to diagnosis. Students are thenrequired to list four important nursing diagnoses and to select one of these as the major nursing diagnosis. This sub-task calls on students to use their content knowledge and attend to important clinical information in order to make an accurate and high quality nursing diagnosis.

In the case of a renal nursing problem (acute poststreptococcal glomerulonephritis) for example, to make accurate nursing diagnoses, students need to know the structure of the kidneys and the function they serve in filtering blood, excreting waste products and in regulating the concentrations of electrolytes in extracellular fluid. Without a well structured accessible content knowledge of the renal system, students are unlikely to recognise the importance of symptoms such as reduced output of urine or recognise the potential dangers associated with a build up of toxins in the blood.

Additionally, the problem solving task requires students to provide a detailed explanation for the choosing the major diagnosis. This sub-task is the primary focus of the teaching strategy and engages students in the task of elaborating on their diagnostic decisions. An analysis of the elaborations provides an indication of the way students actually organise their knowledge and the sort of connections made between relevant prior content knowledge and the clinical data they are dealing with.

For example, to explain the nursing diagnosis of "altered tissue perfusion: renal, cardiopulmonary, related to renal dysfunction" students need to link new clinical data to relevant prior renal knowledge and subsequently elaborate on these connections. The critical feature in the elaborations is how and why information from various sources is brought together. For example, having recognised that the patient has a reduced output of urine and increased levels of toxins in the blood, and knowing that renal disorders give rise to alterations in the body's homeostasis, students should make connections between the two and deduce that the patient's decreased urinary output and increased levels of toxins may be related to kidney dysfunction. Subsequently, the effects of kidney dysfunction on other systems of the body should be inferred. The level of inference involved is hence reflected in the diagnosis nominated as the major diagnosis.

Clearly the teaching strategy described calls on students to use procedural knowledge to systematically approach the clinical task (eg. nursing assessment, diagnostic hypotheses). The task, however, does not focus on the isolation of problem solving processes. Instead, the emphasis is on the qualitatively different ways stored content knowledge is used to process new clinical data. Thus, the task directly taps into the way students actually rearrange their existing content knowledge to make new kinds of knowledge structures to assist in clinical problem solving (Norman, Tugwell, Freightner, Muzzin & Jacoby, 1985).

The purpose of this paper was to compare two models of clinical problem solving in nursing: the widely used hyothetico-deductive model and the more recent knowledge-driven models. Examination of expert novice literature suggested that the heuristic approach of the hypothetico-deductive model provides a necessary but insufficient condition for explaining expert performance in clinical problem solving. It was argued that underlying the efficient use of problem-solving procedures is the elaborateness of the expert's content knowledge. Expertise has been characterised by the interaction of highly organised and accessible content knowledge with appropriate procedural knowledge as the basis for solving clinical problems. On the basis of this interactionist position, a clinical problem solving task aimed at facilitating clinical problem-solving abilities among nursing students was developed.

References

Balla, J.I., Biggs, J.B., Gibson, M. & Chang, A.M. (1990). The Application of Basic Science Concepts to Clinical Problem-solving. Medical Education, 24(2), 137-147.

Barrows, H.S. & Bennett, K. (1972). Experimental Studies on the Diagnostic (Problem-Solving) Skill of the Neurologist, Their Implications for Neurological Training. Archives of Neurology, 26, 273-277.

Barrows, H.S., & Feltovich, P.J. (1987). The Clinical Reasoning Process. Medical Education, 21, 86-91.

Barrows, H.S. & Tamblyn, R.M. (1980). Problem-based Learning. New York. Springer Press.

Benner, P. (1984). From Novice to Expert. Menlo Park, California: Addison-Wesley Publishing Co.

Berner, E.S. (1984). Paradigms and Problem-Solving: A Literature Review. Journal of Medical Education, 59, 625-633.

Biggs, J. B. & Collis, K. (1982). Evaluating the Quality of

Student Learning: The SOLO Taxonomy. New York: Academic.
Bordage, G. (1991). Theory-Practice-Theory: A Health Cycle in Medical Education. Academic Medicine, 9, 1.
Bordage, G., & Grant, J. & Marsden, P. (1990). Quantitative Assessment of Diagnostic Ability. Medical Education. 24, 413-425.
Bordage, G. & Lemieux, M. (1991). Semantic Structures and Diagnostic Thinking of Expert and Novices. Academic Medicine, 9, 70-71.
Bordage, G. & Zac, R. (1984). The Structure of Medical Knowledge in the Memories of Medical Students and General Practitioners: categories and prototypes. Medical Education, 18, 406-416.
Bornor, J. & Durrell, K. (1987). Reliability and Validity of the "triple jump exercise" in Assessing Clinical Reasoning Skills. In Hart, I. & Harden, R (Eds.). Further Developments in Assessing Clinical Competence. Can-Heal Publishing.
Chi, M.T.H., Glaser, R. & Rees, E. (1981). Expertise in Problem Solving. In R. Sternberg (Ed.), Advances in the Psychology of Human Intelligence. Vol. 1, pp 7-75. Hillside, NJ: Lawrence Erlbaum Associates.
Carr, J. (1991). What Do Physiotherapists Do When Doing Physiotherapy? And, What Do Undergraduate Students Do When Learning Physiotherapy: Proceedings Australian and New Zealand Association for Medical Education Conference.
Carnevali, D.L. (1984). The Nursing Domain for Diagnostic Reasoning. In Carnevali, D.L., Mitchell. P.H., Woods, N.R. & Tanner, C.A. (Eds.), Diagnostic Reasoning in Nursing. New York: J.B. Lippincott Co.
Cholowski, K. & Chan, L.K.S. (in press). Diagnostic Reasoning Among Second Year Nursing Students. Journal of Advanced Nursing.
Claessen, H.F.A. & Boshuizen, H.P.A. (1985). Recall of Medical Information by Students and Doctors. Medical Education, 19, 61-67.

Clarke, R. (1988). Problem-Learning. In Cox, K.R. & Ewan, C.E. (Eds.). The Medical Teacher. Edinburgh. Churchill Livingstone.
Clement, J. (1983). Analogical Problem Solving in Science and Mathematics. Paper presented at the annual meeting of the American Research Association, Montreal Canada.
Davis, R.B. (1984). Learning Mathematics: The Cognitive Science Approach to Mathematics Education. Norwood, Nj: Albex.
De Volder, M.L. & De Grave, W.S. (1989). Approaches to Learning in a Problem-based Medical Program: a

developmental study. Medical Education, 23, 262-264.
Elstein, A.S., Shulman, L.S. & Sprafka, S.S. (1978). Medical Problem Solving: An Analysis of Clinical Reasoning. Cambridge, Massachusetts: Harvard University Press.
Ellis, H.C. & Hunt, R.R. (1989). Fundamentals of Human Memory and Cognition. Dubuque. Iowa: Wm. C. Brown.
Gale, J. (1982). Some Cognitive Components of the Diagnostic Thinking Process. British Journal of Educational Psychology, 52, 64-76.
Gale, J. & Marsden, P. (1982). Clinical Problem Solving: the Beginning of the process. Medical Education, 16, 22-26.
Gale, J. & Marsden, P. (1983). Medical Diagnosis: From Student to Clinician, Oxford: Oxford University Press.
Grant. G. & Marsden. P. (1987). The Structure of Memorised Knowledge in Students and Clinicians: and explanation for diagnostic expertise. Medical Education, 21, 92-98.
Glaser, R. (1984). Education and Thinking, American Psychologist, 39(2), 93-104.
Gordon, M. (1980). Predictive Strategies in Diagnostic Tasks. Nursing Research, 29(1), 39-45.
Grant, J. & Marsden, P. (1987). The Structure of Memorised Knowledge in Students and Clinicians: an explanation for diagnostic expertise. Medical Education, 21, 92-98.
Grant, J. & Marsden, P. (1988). Primary Knowledge, Medical Education and Consultant Expertise. Medical Education, 22, 173-179.
Groen, G.L. & Patel, V.L. (1985). Medical Problem-solving: some questionable assumptions, Medical Education, 19, 344-356.
Groen. G. J. & Patel. V.L. (1988). The Relationship Between Comprehension and Reasoning in Medical Expertise. In Chi, M.T.H., Glaser, R. & Farr. (Eds.). The Nature of Expertise. London: Lawerence Erlbaum Associates.
Hamilton, R. (1990). The Effect of Elaboration on the Acquisition of Conceptual Problem-Solving Skill from Prose. Journal of Experimental Education, 59(1), 1-17.
Holbert, C. M. & Abraham, C. (1988). Reflections on Teaching Generic Thinking and Problem Solving. Nurse Educator. 13(2), 23-27.
Itano, J.K. (1989). Comparison of the Clinical Judgement Processes in Experienced Registered Nurses and Student Nurses. Journal of Nursing Education, 28(3), 120-126.
Jones, J.A. (1988). Clinical Reasoning in Nursing. Journal of Advanced Nursing, 13, 185-192.

Kagan, D.M. (1988). Teaching as Clinical Problem Solving: A critical Examination of the Analogy and Its Implications. Review of Educational Research, 58(4), 482-505.
Kaufman, D.R. & Patel, V.L. (1991). Problem Solving in the

Clinical Interview: A Cognitive Analysis of the Performance of Physicians, Residents, and Students. Teaching and Learning in Medicine. 3(1), 6-14.
Lesgold, A., Rubinson, H., Feltovich, P., Glaser, R., Klopfer, D. & Wang, Y. (1988). Expertise in a Complex Skill: Diagnosing X-Ray Pictures. In Chi, M.T.H., Glaser, R. & Farr. (Eds.). The Nature of Expertise. London: Lawerence Erlbaum Associates.
Little. P. & Ryan. G. (1988). Educational Change Through Problem-based Learning. Australian Journal of Advanced Nursing. 5(4), 31-35.
McGurie, C.H. (1985). Medical Problem-Solving: A critique of the Literature. Journal of Medical Education, 60, 587-595.
McMillian, M.A. & Dwyer, J. (1989). Changing times, changing paradigm (2): The Mcarthur experience. Nurse Educator Today, 9, 93-99.
McMurray, A. (1989). Time to extend the "process"?. Australian Journal of Advanced Nursing. 6(4), 40-43.
Neufeld. V.R. & Norman. G.R. (1985). Assessing Clinical Competence. New York. Springer Pub. Co.
Neufeld, V.R., Norman, J.W., Feightner, J.W. & Barrows, H.S. (1981). Clinical Problem-solving by Medical Students: a cross-sectional and longitudinal analysis. Medical Education, 15, 315-322.
Neufeld, V.R., Norman, G., McAuley, R., Repo, R. & Henry, N. (1983). The Triple Jump Exercise - A Further Study of Standardisation and Inter-rater Reliability. McMaster University. n.p.d.
Norman, G.R. (1988). Problem-solving Skill, Solving Problems and Problem-based Learning. Medical Education, 22, 279-286.
Norman, G. R., Brooks, L. R., Allen, S.W. & Rosenthal, D. (1990). Sources of Observer Variation in Dermatologic Diagnosis. Academic Medicine, 9, 19-20.
Norman, G.R., & Patel, V.L. & Schmidt, H.G. (1990). Clinical Inquiry and Scientific Inquiry. Medical Education, 24, 396-399.
Norman, G.R., Tugwell, P., Feightner, J.W., Muzzin, L.J. & Jacoby, L.L. (1985). Knowledge and Clinical Problem-solving. Medical Education, 19, 244-356.
Patel, V.L., Evans, D.A. & Groen, G.J. (1989). Reconciling Basic Science and Clinical Reasoning. Teaching and Learning in Medicine. 1(3), 116-12
Patel, V.L., Evans, D.A. & Kaufman, D.R. (1990). Reasoning Strategies and the use of Biomedical Knowledge by Medical Students. Medical Education, 24, 129-136.
Patel, V.L., Groen, G.J. & Norman, G.R. (1991). Effects of Conventual and Problem-based Medical Curricula on Problem Solving. Academic Medicine, 66(7), 380-389.

Patel, V.L., Groen, G.J. & Scott. H.M. (1988). Medical Education, 22, 398-406.

Pavin, C., Neufeld, V., Norman, G., Walker.I. & Whelan, G. (1979). The "Triple Jump" Exercise - A Structured Measure of Problem Solving and Self-Directed Learning. McMaster University. Hamilton, Canada. n.p.d.

Prawat, R. (1989). Promoting Access to Knowledge, Strategy, and Disposition in Students: A Research Synthesis. Review of Education Research, 59(1), 1-39.

Putnam, R.T. (1987). Mathematics Knowledge for Understanding Problem Solving. International Journal of Education Research, 11, 687-705.

Ramsden, P., Whelan.G. & Cooper. D. (1989). Some Phenomena of Medical Students' Diagnostic Problem-solving. Medical Education, 23, 108-117.

Roth, K.J. (1990). Developing Meaningful Conceptual Understanding in Science. In Fly Jones, B. & Idol, L., (Eds.), Dimensions of Thinking and Cognitive Instruction. London: Lawrence Erlbaum.

Schmidt, H.G. (1983). Problem-based learning: rationale and description. Medical Education, 17, 11-16.

Schmidt, H.G., Norman, G.R. & Boshuizen, H.P.A. (1990). A Cognitive Perspective on Medical Expertise: Theory and Implications. Academic Medicine, 65(10), 611-621.

Silver, E.A. & Marshall, S.P. (1990). Mathematical and Scientific Problem Solving: Findings, Issues, and Instructional Implications. In Fly Jones, B. & Idol, L., (Eds.), Dimensions of Thinking and Cognitive Instruction. London: Lawrence Erlbaum.

Thompson, C.B., Ryan, S.A. & Kitzman, H. (1990). Expertise: the basis for expertise system development. Advanced Nursing Science, 13(2), 1-10.

Whelan, G. (1986). Improving Medical Students' Clinical Problem-solving. In Ramsden, P. (Ed.), Improving Learning: new perspectives. New York: Nichols Publishing.

Woloshyn, V.E., Pressley, M. & Schneider, W. (1992). Elaborative Interrogation and Prior-Knowledge Effects on Learning Facts. Journal of Educational Psychology. 84(1), 115-124.

Yeaw, E.M.J. (1979). Problem Solving as a Method of Teaching Strategies in Classroom and Clinical Teaching. Journal of Nursing Education, 18(7), 16-22.